

Agricultural Research Institute, Pusa

THE MILLING AND BAKING QUALITIES OF INDIAN WHEATS

No. 2

SOME NEW PUSA SELECTIONS TESTED IN 1909

BY

ALBERT HOWARD, M.A. (Cantab.), A.R.C.S. (Lond.), F.C.S., F.L.S.,
Imperial Economic Botanist

AND

GABRIELLE L. C. HOWARD, M.A.,
Associate and late Fellow of Newnham College, Cambridge



CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA

THE MILLING AND BAKING QUALITIES OF INDIAN WHEATS

No. 2. Some new Pusa Selections tested in 1909.

THE milling and baking qualities of Indian wheats have been discussed by us in a previous paper.¹ Samples of ten Indian wheats, grown in various parts of the Indo-Gangetic plain in the wheat-growing season of 1907-08, were submitted to Mr. A. E. Humphries, Chairman of the Home-grown Wheat Committee of the Incorporated National Association of British and Irish Millers, a well-known authority on questions relating to the milling and baking of wheat. It was clear from the report that the wheats sent for testing varied very greatly both in the strength of the flour and in general milling qualities. The harder samples were notably superior to the soft wheats like Mozaffernagar white, the cultivation of which has been so persistently advocated for the export trade. The best of the ten wheats was Pusa 6, a hard white beardless wheat grown at Pusa from a single plant. This wheat proved to be free grinding and gave a lively greyish white granular flour which yielded a tough dough and large loaves with a superior crust and better general appearance than the bread from the other nine. Mr. Humphries stated in conclusion "I unhesitatingly express the opinion that Pusa 6 is the best and I can quite as unhesitatingly say I do not like Australian 27 or Mozaffernagar grown at Mozaffernagar." After Pusa 6, three Punjab wheats—*Lal kasarwala*, Punjab Type 9, and Gujar Khan—gave the next best results and it is interesting to notice that these wheats are greatly preferred by the cultivators of the Punjab to the soft whites like Australian 27 and Mozaffernagar the cultivation of which has been so much recommended. On the general question of the best wheats to be recommended to the cultivators we expressed the emphatic opinion that the wheats most in favour with the people for their own consumption are those in greatest demand by the Home millers and further are those which will command the highest price in England.

¹ Howard & Howard, *Bulletin 11, Agricultural Research Institute, Pusa, 1908.*

We further pointed out that, consequent on the revolution in milling due to the now exclusive use of roller mills, the cultivation of soft white wheats like Mozaffernagar is a mistake and had been the means of lowering the position of India as a wheat producing country in the estimation of the Home millers and this mistake has consequently entailed the loss of a large sum of money to the Indian cultivator. What the Home miller wants is a free grinding dry wheat of uniform texture or consistence which will yield the maximum amount of strong flour. Such wheats we consider are most likely to be found among those most in demand for local consumption and will naturally be what are commonly known as hard wheats. The colour whether red or white is not now of much consequence, red wheats being of practically the same value as white. In addition, many of the Indian hard wheats are more easily grown, are hardier, more rust resistant, require less moisture and often yield better than the soft whites. From all points of view therefore their culture is desirable.

The publication of these views naturally did not pass without comment. This is not surprising considering that our recommendations, if proved to be well founded, will revolutionise the wheat industry of this country and lead to the rapid advance of India in competition with the wheat producing countries of the world.

The recommendations contained in the paper referred to were submitted by the Director of Agriculture of the Punjab to the President of the Incorporated National Association of British and Irish Millers and the matter was considered at a meeting of the Council of the Association held in Mark Lane on April 23rd last. The result of the deliberations which took place were published in the *Miller* of May 3rd, 1909, and are reproduced below:—

“On Friday, April 23rd, a meeting of the Council of the Incorporated National Association of British and Irish Millers was held at the offices of the Association, 59, Mark Lane, when Mr. William Edgar Nicholls presided.

Indian Wheat.

The next item on the agenda was:—To consider correspondence received *re* Indian wheats.

Mr. A. E. Humphries, in placing this matter before the meeting, said considerable importance was attached to this matter

by the Indian Government, and he had had a large amount of correspondence with Indian Government officials relating to it. He had conducted the correspondence to the best of his ability, but he had pointed out to the officials of the Indian Government that the expressions of opinion he had made were his own, and that they did not bind the association in any way. He should like to know whether the members of the Council criticised or confirmed it. The Indian Government had been seeking to make the Indian growers grow wheat suitable for the export trade, instead of growing wheats which were more suitable for local requirements.

Continuing Mr. Humphries said:—

The position disclosed by the correspondence forwarded to the President and a considerable correspondence which I have had with Government officials in India amounts to this:—

The wheats which the natives were inclined to grow about 30 years ago were harder by nature than those which millers in millstone days or in the transitional period from millstones to rolls really wanted.

Following upon the very valuable reports which Messrs. Macdougall Brothers then presented, the authorities met with a great amount of success in getting the natives to grow softer whiter wheats, so as to suit what was then undoubtedly the requirements of the English market. Since then we as millers have entirely discarded millstones, and learnt the advantages of wheat conditioning.

I first of all had a large number of samples sent to me for my opinion, to be ascertained on appearance only. Later I had 10 samples sent to me for milling and baking. All these samples were known by botanical names, and not by commercial ones, but those known as Mozaffernagar and "Australian 27" represented approximately the softer weaker whites such as White Delhi.

In arriving at my opinion, I conditioned these wheats carefully to a full commercial extent, and in my opinion any wheats which then became soft in the sense of woolly were not nearly so good as those which remain free milling after full conditioning. Under such conditions these soft white wheats did mill badly. They required greater force to effect separations, and though they gave a white-hued flour, some of them, probably because of the extra force required in grinding, were dingy.

One wheat in particular I singled out as particularly good. It was a white wheat, not unlike White Fife in appearance, very bright, conditioned very well indeed, ground very freely and very well, gave an altogether lively flour, bright-hued rather than white and the bread had an altogether better appearance than that from ordinary Indian wheat. I understand that this wheat was raised from a single head, which was found growing among others, that it is rust resistant, a good yielder, and one which weevils do not attack freely. Without telling me so, the Indian Government had submitted the same wheats to a chemist in India, and he, relying principally upon the percentage of total nitrogen, placed substantially the same series into, for all practical purposes, the same order of merit as I had done by milling and baking. This means that whereas the soft white wheats contained only 1.3 per cent. to 1.4 per cent. total nitrogen, the white wheat upon which I reported very favourably contained 2.52, or nearly twice as much—a percentage that would compare very favourably with some of the so-called strong wheats of the world. This was of course very satisfactory to me, for it provided quite indirectly a striking confirmation of the correctness of my work, for after all said and done and in spite of exceptions, total nitrogen is a very useful indication of a flour's strength.

I recently received letters from Government officials, which I do not suppose were meant to be confidential, in which they wanted to know whether it was desirable to send forward bulks of, say, 40 to 100 sacks, and get them priced here on the market, the idea being that such evidence would indicate to the grower the superiority of these new sorts, and be an inducement to grow them. My reply in essence was this. I do not think that the true value of new wheats can be ascertained in that way. Any person buying a novelty would regard it with a certain amount of suspicion, and human nature being what it is, would seek to buy at the lowest price possible. But that, having regard to the fact that it was a distinct advantage to the grower on the ground of financial yield, apart altogether from the relative commercial values of the wheats on our markets to grow these new varieties, the proper course was to put it to the agricultural public of India in that light, adding that opinions which had been obtained indicated that the wheat was likely to obtain higher prices. There is, at any rate, one

millers in the kingdom who would willingly absorb several hundred tons, which is more than they are likely to send for some years of "Pusa 6," at prices substantially higher than any Indian wheat he knows at present, and it seemed to me altogether more desirable to distribute such good stuff as seed and get a large bulk to deal with, rather than send it over here to be submitted to an altogether second rate method of testing commercial value.

The Director of Agriculture in the Punjab has written to the Secretary of the Kurrachee Chamber of Commerce drawing his attention to bulletin, which consists largely of my report, and sent a copy of that letter to the President. I think, instead of reading a rather long document, it may be desirable if I summarised the statements I made, and I do not think that any member of this Council would have any difficulty in agreeing with them.

I have been careful to point out that in some sections of the country a soft white flour is even now preferred: that we English millers realise that a white wheat may be as strong or stronger than a red wheat. That if on other points wheats are the same, preference would be given to a white wheat. That, in any case, we prefer a wheat which after conditioning in the modern sense of the term remains free grinding and does not become "woolly." That on an average of years weak wheat is in more plentiful supply than strong wheat, and that as a consequence strong wheats are usually more valuable than weak ones. That if Indian exporters want to secure maximum value for their wheats, they must not mix common ones with fine ones, also that they must not water their wheats before shipment.

To my mind the most important point of all the foregoing is that the wheats which best suit me, and which I think would suit the majority of British millers, do in point of fact best suit the Indian grower. My belief as regards India as well as England is that the grower should produce what best suits his interests, and that we millers, nowadays, are so much better equipped technically than we used to be 30 years ago that we can tackle any ordinary wheat of commerce at some price or another. If, therefore, the immediate interests of the grower, more particularly as to the yield per acre be considered, we millers will be content, and the grower can rely on getting a fair market value for whatever wheats he produces. If he produces wheats which do not realise quite so

much on our markets, it might pay him on account of extra yield to produce them, but nothing could be better both from the English millers' point of view and the Indian growers, than that they should produce and sell separately such fine wheats as the Government officials now seem to have in hand, inasmuch as they are likely to suit British millers and the grower as well.

Dealing with one point arising out of the letter the President has received, I do not know, and would not like to predicate with certainty, what would happen if they grew these fine wheats on irrigated land. That is a matter for investigation, and I might add that a further batch of Indian wheats are now being forwarded from the Government Experimental Stations in India for further milling and baking tests.

I have, throughout this correspondence, been careful to say that I was expressing my own opinions, and not in any degree seeking to bind anybody but myself. However much any person in this room may disagree with anything I have said, I am sure we are absolutely unanimous in wishing to see a great increase in the production and export of Indian wheat. Our interest is in that direction, and not in the other, as has recently been suggested in high quarters, and that we are willing to do anything we can to facilitate the production of wheat in India and in the British Empire.

The President said a letter had been addressed to the Association by the Director of Agriculture, in which he said he enclosed a copy of the bulletin, and he would be grateful if the Association would carefully consider the matter. He thought the best plan would be to send a letter on the lines of what Mr. Humphries had just reported. The important thing was that Mr. Humphries had had a good deal to do with this matter, and he was more competent to speak for the Association than any other member, and this report, if adopted, would fully cover the whole ground. He would really suggest that the official reply of the Association should take that form, subject to what any member might happen to have to say in criticising the matter.

Mr. Joseph Rank seconded the proposal.

Mr. Voller said the broad lines recommended by Mr. Humphries were eminently desirable for increasing the export of Indian wheats to this country. The type of wheat sent was a very good one,

and he would suggest that further samples, when they arrive, should be sent to members of the Council. Mr. Humphries' report covered broadly what was required from that Association, and he thought the Association might emphasise the point he had made, especially having regard to quality and quantity.

The President thought that if this communication went out over the signature of the President of the Association it would cover all the points raised.

The resolution was then formally put to the meeting, and carried unanimously, that the reply of the Association take the form of Mr. Humphries' report.

It will be seen that the recommendations based on Mr. Humphries' first report were unanimously endorsed by the Council of the National Association of British and Irish Millers and that as far as the Home market is concerned there will be no difficulty in disposing to advantage of any Indian wheats of good strength and high milling qualities.

Out of the large number of hard wheats, high in nitrogen, isolated by us at Pusa and now in various stages of multiplication from single plants, only one, namely, Pusa 6, was sent for a milling test in 1908. During the last season, 1908-09, a number of others passed successfully throughout the preliminary field and laboratory tests and representative types (Nos. 20 to 29) of these wheats were this year (1909) submitted to Mr. Humphries for complete milling and baking tests. Some of the most promising selections were not included however as the seed at our disposal was insufficient for a full test. These we hope to send to England in 1910. The new Pusa wheats tested in 1909 are for the most part rapidly maturing types with good straw and other agricultural characters combined with grain uniform in texture and high in nitrogen. The Pusa selected wheats, Nos. 20 to 29, with four other samples sent, were as follows:—

No.	Name.	Where grown.	Nitrogen. Per cent.
6	Indian Fife	Cawnore	1.54
7	Beardless Mozaffernagar	1.74
17	Bombay Dissi	Kareli	1.67

S THE MILLING AND BAKING QUALITIES OF INDIAN WHEATS.

No.	Name.	Where grown.	Nitrogen Per cent.
18	Jubbulpore Pissi	Jubbulpore	1.99
20	Selected Gangajali	Pusa	2.52
21	Selected Hara	"	2.55
22	White selected Jana Khar	"	2.33
23	Red selected	"	2.58
24	Pusa 6a	"	2.5
25	Pusa 7	"	2.39
26	Pusa 8	"	2.39
27	Pusa 10	"	2.10
28	Pusa 11	"	2.08
29	Pusa 12	"	1.98

For the nitrogen determinations we are indebted to Mr. H. E. Annett, Officiating Imperial Agricultural Chemist. It will be seen that the Pusa selections are generally much higher in this constituent than the two Pissis and the two Cawnpore samples. The samples of Bombay Pissi and Jubbulpore Pissi were obtained from Messrs. Ralli Brothers and were representative trade samples of the soft white wheats grown for export on the black cotton soils of Peninsular India and they were included for comparison with the Pusa wheats. Indian Fife and beardless Mozaffernagar were grown on the Cawnpore farm and were included at the special request of Mr. B. C. Burt, Deputy Director of Agriculture in the United Provinces. Indian Fife is said to be derived from a cross made by the late Mr. Farrer of New South Wales between Canadian Red Fife and an Indian wheat. Beardless Mozaffernagar is said to have been obtained from the Mozaffernagar District. All the Pusa grown wheats are selections and have been grown from plants found in the exceedingly mixed crops which resulted from the sowings of a large collection of Indian wheats made at Pusa in 1905.

Mr. Humphries' report on these wheats is given below:—

Report by Mr. A. E. Humphries, Past President of the Incorporated National Association of British and Irish Millers on the samples of Indian wheats sent from Pusa by the Imperial Economic Botanist in May 1909.

" I duly received the 28¹ sample lots of wheat numbered 1 to 29 inclusive, number 19 omitted, grown in India during the cereal year 1908-09. They arrived without mishap in good condition, particularly free from dirt and extraneous matter, and as the wheats with two or three exceptions were well developed, nature and the growers by their combined efforts had succeeded in producing very fine specimens of Indian wheat.

" I ascertained the natural moisture of each of these sample lots on arrival, cleaned and 'conditioned' part of each one according to its individual requirements, milled that part separately noting how it behaved in grinding and separating, and then baked separately the flour obtained from it. If the baker would in commercial practice make elaborate tests of each lot of flour he receives, and finally give it the treatment in fermentation and handling by which it would yield optimum results, many of the wide differences of opinion concerning wheats and wheaten flours would disappear or be most materially minimised, but that is a counsel of perfection and the baker requires in commerce flours which show a minimum of deviation from recognised standards and necessitate little or no adjustment of his usual methods.

" With these ideas in my mind, I subjected each of the flours obtained from the first milling of these sample lots of wheat to the same bakehouse treatment, and noted the results. The necessity for variations in treatment, if optimum results were to be obtained, was most clearly shown. Further variations in treatment were also necessary in conditioning and milling. I have recently, in a paper read at the Winnipeg meeting of the British Association, pointed out that the skilful use of water at the right stages, brought about important changes in the quality of flour, that there could be no fixed standard of moisture content applicable to all flours, and that to secure optimum results some wheats or flours should have a low moisture content, some a high one. I applied these ideas in milling and baking the 28 sample lots a second time, some of them a third time.

¹ Fourteen of these samples are concerned with an investigation (in collaboration with Mr. H. M. Leake, Economic Botanist to the Government of the United Provinces), on the factors which influence the quality of Indian wheat. The report on these samples will be published shortly.

" In different countries, or even in different parts of the same country, opinions as to what constitutes ideal quality differ very widely. For instance, in London practically all bread is made by professional bakers, in Yorkshire by housewives; in some parts loaves are baked in tins whereby the dough is not required to maintain its shape unaided, as it would be if tins were not used. Again, for some purposes flours are not subjected to yeast fermentation at all, whereas for others they have to withstand a very long fermentation.

" There are similar divergencies as to what constitutes good colour in flour. Some like flour to be white of chalky hue, some prefer it to be white of creamy hue. All this means, that wide differences of opinion can properly be entertained by various authorities as to some points of quality. But there are points on which all millers are agreed. They want all samples of wheat to be uniform in texture. That is absolutely necessary if optimum results in milling are to be obtained, and the most recent developments in milling are making this more important than ever. I know that these irregularities in texture may be due to the effects of soil, season, and water supply, but in so far as they are due to varietal causes they should be avoided, and I am very pleased to see how very regular in texture some of the 28 sample lots sent me are. Millers are also unanimous, or practically unanimous, in preferring wheats which 'mill freely' in other words, those wheats which can be ground easily and which can be divided out into their ultimate commercial constituents of flour and offal (husk) with the greatest ease. In this connection I should like to point out an error frequently made, when it is said without qualification that millers want hard wheats. Some wheats are said to be hard when in fact, they are merely dry. If water be added to them they become soft, perhaps 'woolly.' Other wheats are really hard even when their moistures are relatively high. Millers do not like wheats which are soft and woolly when their moistures are adjusted. Such wheats would require 20 to 50 per cent. more grinding to effect a proper separation of husk from kernel in the early stages of milling, and in the later it is difficult to effect separations at all easily. At the other extreme are the Durums, which are really hard by nature and remain hard even if their moistures be raised very considerably. Within the

last few years millers have learned how to minimise their objections to these wheats, but the objections remain, though in diminished degree. We do not want wheats to be as hard as Durums, and in particular we do not like any sorts to be horny as well as hard. It is difficult to specify a word which exactly fits the case. On the one hand we certainly do not want soft woolly wheats, on the other we do not want really hard or horny wheats. What we do like are those which when conditioned are mellow and free grinding. We want an adjective which expresses the commercially important point better than 'hard' and for lack of better I suggest 'free-milling.' This is meant to express a characteristic highly esteemed by all millers, which enters into their calculations in estimating relative commercial value.

"I want now to amplify a statement of opinion indicated in a former report, and endorsed unanimously by the Council of the National Association of British and Irish Millers. I entertain the view very strongly, that the grower in any country or district should produce those varieties of wheat which yield him the best possible financial return. In that way, the public interest also is in my view best served. Within the last 20 years, the technical equipment of the best mills has been very greatly improved. Millers can now make better use of a wheat's potentialities and overcome the objections which their predecessors had to certain varieties. To a very great extent, some wheats have realised relatively low commercial values, not so much because they were bad according to some definite standard of real excellence, but because they did not conform to some preconceived ideas on the part of millers, bakers or the public as to their behaviour or appearance. Many people still think that it is wrong to adopt any new process of making food, merely because it is new, especially if it be introduced or worked by chemists, but fortunately this unintelligent prejudice is entertained by a minority. Millers are, therefore, able to make vital changes in their recommendations to Indian wheat growers. Messrs. Macdougall Brothers, whose ability to form correct opinions no one will question, in reporting to the Indian Government 30 years or so ago, pointed out that the varieties of wheat which Indian growers favoured, were unsuitable for export; and they recommended the encouragement of certain other types of wheat. Fortunately for the growers

and the world generally, this advice can now be superseded. The attitude of British millers towards Indian and other wheats is, that they are willing to pay relatively high prices for the best varieties, but they will buy at fair but lower prices wheats of inferior quality. They believe, however, that a combination of fine quality and high yield per acre is no longer an impossibility, if it ever were so, but they are content to leave to the growers and their competent botanical advisers, the decision as to what varieties shall be produced. Applying these ideas to important details, British millers are now able to obtain flour of first rate colour from redskinned wheats. They would give a preference to white wheats if in all respects they were equal to red, but the difference in commercial value due to the whiteness of husk is nowadays very small. On the other hand, millers know quite well that 'strength' as applied to baking values, is not caused by or correlated with redness of skin, so on this point of appearance growers can now please themselves. Much more important points concern hardness and softness of endosperm, and toughness or friability of skin. The miller for generations has sought to exclude as much husk as possible from his flour. Thirty years ago, millstones were in common use, and as they applied a great amount of friction in an intense form, the miller wanted, and for the highest commercial purposes would have mellow wheat with tough skins. Hence Messrs. Macdougall's recommendations. But now that the change in the nature of wheats available has imposed on millers the adoption of modern gradual reduction by rollers, with its concomitant diminution in the amount and intensity of friction applied in grinding, mellow wheats with tough skins are no longer a necessity. If, therefore, the grower can get better results by producing harder and as they used to be called commoner wheats, he will satisfy the miller in doing so. Indeed, most millers now that they are properly equipped with modern machinery prefer the wheats which I have called 'free-milling' to softer ones.

Another point of change concerns colour. Some wheats of the *Triticum vulgare* type and all the Durums yield flour which is intensely yellow in hue. I am not aware that extreme yellowness implies either goodness or badness in dietetic value. As a rule the Durums seem to contain more natural sugar and produce more by diastatic action during baking processes than 'ordinary' wheats

They certainly yield bread of relatively pleasant flavour and at least several varieties of that type contain relatively high percentages of nitrogenous matter. Yet apart from the troubles in milling them, the popular taste and demand, which in the last resort determines commercial values as regards some important qualities, hold their extreme yellowness of hue in low esteem. But now that artificial bleaching has been successfully applied, and so long as our authorities continue to regard that process as permissible in the public interest, the British miller, knowing that in certain districts Durums withstand drought and rust better than 'ordinary' wheats, will acquiesce in their production and will buy them at their fair commercial value. He knows however, that the application of Mendelism to wheat may render it possible to get the desirable characteristics of Durum combined with other desirable characteristics of some 'ordinary' wheat, and he lives in the hope and expectation that great improvements in both yield and quality will result from the most recent applications of botanical science.

"It should be borne in mind also, that India is not at all likely in the near future to supply the entire wants of the United Kingdom, so that British Millers can by blending Indian wheats with other sorts, take almost anything that comes, whatever it may be as regards quality.

"The cumulative effect of all the foregoing considerations is to emphasise the point that the interests of the Indian producer should be paramount, but it is true also that some Indian wheats are much better and will command higher prices than others.

"After the detailed and elaborate tests I have made of the 28 samples submitted to me, I entertain no doubt as to the great superiority of some of them, and shall be extremely pleased to find that one or more of the varieties which I esteem the best, are also those which best suit the average Indian producer.

"For the sake of lucidity, and as an aid to myself in arriving at my conclusions, I have divided the 28 lots into groups.

Pissis.

"No. 17 is described as Bombay Pissi. No. 18 as Jubbulpore Pissi. These might properly have been grouped with the Mozaffar-

nagars inasmuch as they are very mellow and yield a soft white flour. The Bombay Pissi sample contains a few red grains. The Jubbulpore might be described as a mixture of white and red grains, and contained a few red ones which appeared to be Durum. However both behaved in milling as soft woolly wheats.

"The Bombay yielded flour of a chalky white hue, and the bread produced from it had an unattractive appearance both in crumb and crust. The Jubbulpore sample yielded a soft feeling flour not so chalky white as the Bombay, and the bread made from it had a better appearance in crumb and crust than the Bombay. This was probably due to the presence of the Durum grains which would act as a corrective to the chalky whiteness of the Pissi part of the sample. I entertain a poor opinion of these wheats for bread-making purposes if used by themselves, but they would be useful for blending if a miller wished to counteract the extreme yellowness of some varieties, and they would be suitable for making pudding or biscuit flour, so if the natives of any district wish to grow them they need not be discouraged from doing so. I am quite sure, however, that in my opinion they are far from being the best of the 28 lots sent me. They behave poorly in milling, and I do not like the bread they yield, which is not only in my opinion poor in appearance, but poor or bad as regards flavour. For size and shape of loaf they are about equal to the better Mozaffernagars.

The Pusa Nursery group.

"Numbers 24 to 29 inclusive of the set sent me are known under the laboratory numbers Pusa 6a, Pusa 7, Pusa 8, Pusa 10, Pusa 11, and Pusa 12. They are mellow wheats not unlike the Mozaffernagars in general external appearance, but as a group they are superior to the Pisis and Mozaffernagars. The size and shape of berry is attractive. Some of them remind me of the New Zealand Tuscan and the English Talavera wheats at their best, but of course these Indian wheats are much drier. All of this group behaved well in milling with the exception of No. 28 (Pusa 11). They yielded white flour with the exception of 29 (Pusa 12). No. 26 (Pusa 8), contained a fair proportion and No. 29 a large one of translucent grains. That means, that the flours from

these lots were not so white as the others, indeed the produce of 29 would have to be described as yellow and granular but both were bright and attractive. For colour of bread No. 26 came out first of this group. No. 29 is too yellow without bleaching if used by itself. The bread from No. 28 had a particularly nice external appearance; No. 25 a much better flavour than ordinary Indian. The strength of this group is a great surprise to me. I should not have thought from the appearance of the wheats that they could be described as strong, and though they are not so strong as Manitoba or United States Spring Wheat, they are very much stronger than any Indian wheats I had previously handled. By appearance I had placed No. 26 (Pusa 8) at the head of the group, and the baking results confirm that estimate. It does yield in a substantial degree that toughness of dough characteristic of American Spring Wheat, in other words, it is quite unlike and much superior to the Indian wheats we ordinarily get in commerce. No. 29 is only slightly behind 26 in this respect, and Nos. 27 and 28 are only a little behind 29. I can, however, unhesitatingly say that 26 is the best of the group. It represents a combination of good milling points, first rate behaviour as dough, and first class colour in bread.

"Nos. 21, 22 and 23.—These wheats labelled respectively 'selected Hara,' 'White selected Jana Khar' and 'Red selected Jana Khar' are in my opinion very attractive. The Hara is a small round berried red wheat of a particularly deep red hue, very even in texture, and contains no soft or pale grains. The hue is peculiar and that point is not a good one. The Red Jana Khar may be called a sister wheat to the Hara. This also has a peculiar hue, almost that of dark mahogany. It is larger in berry than the Hara, and like it contains no pale or soft corns whatever. The white Jana Khar is of particularly nice appearance, mostly round berried, of Pife shape, distinctly hard as received, very translucent without any pale or soft corns in the sample. These three wheats behaved particularly well in conditioning and milling, and that weighs greatly in my opinion. Of the three, the white Jana Khar is the best on that point. Although they are hard, the flours they yield are not yellow, and the bread has the hue which one associates with Manitoba wheat, a greyish but bright white. In these three cases the toughness of dough characteristic

of American Spring wheat, again occurs; and is in my view most noteworthy. The breads are very attractive in appearance, with first rate pile and beautiful crusts. The loaves are not so big as those which British bakers obtain from Manitoba or American Spring wheat flours, but they yield that type of bread, and if some malt extract were added in milling or baking to break down still more the effects of great hardness, I believe that truly superb bread would be obtained from them. With only small quantities of wheat available I could not experiment more than I have done with these wheats, and in all these trials I have used flour, yeast, salt and water only, but if I had more wheat of these three sorts, I would have carried on still further modifications in conditioning, milling and baking, in the belief that they, fine though they now are, would have responded satisfactorily to further treatment. Millers or merchants buying wheats on appearance would prefer the White Jana Khar. It also mills better than the other two, but the Red Jana Khar behaves best in the bakehouse. On balance however, and having regard to the results which would probably ensue from further adjustments of milling and bakehouse treatment, I should say, that the White Jana Khar is the best of the three.

"No. 20 (Selected Gangajali) appears to be a Durum, the only one in the entire set of samples. It is very good of its kind, and because it is not horny in texture mills better than many Durums, do. The flour is a good colour of its class, the bread made from it was of very fair colour and of distinctly pleasant flavour. This means that if for economic or botanical reasons it be desirable to grow Durums, this variety is one to be recommended.

Remainder.

"I have now dealt with all but Indian Fife (No. 6), Beardless Mozaffernagar grown at Cawnpore (No. 7). The 'Indian Fife' is fine looking white wheat. I understand it is neither the red nor the white Canadian Fife but quite a different wheat obtained by Farrer in Australia as a result of crossing Fife and an Indian variety. The sample lot sent me is very irregular in texture, so it cannot be handled to the greatest advantage in milling and baking. Several of the other wheats sent me yield better flour and bread than this one.

"The hardless Mozaffernagar is altogether stronger in appearance than the ordinary Mozaffernagars sent me. It contains a large proportion of translucent berries, so the flour is neither soft nor white looking. It mills very freely, and makes bread of yellow hue. It is about as strong as the best ordinary Mozaffernagars, but as it is uneven in texture and is somewhat non-descript in its characteristics, I prefer several others of the 28 lots sent me.

Summary.

"From the foregoing remarks it will be gathered that several of the wheats sent me are very good. The most significant is No. 26 (Pusa 8). In No. 22 (White Jana Khar) regarded as typical of its group we have a wheat which looks really good and is so. It yields a granular lively flour, and in the estimation of most bakers a really stable and strong flour is granular. But in the case of No. 26 (Pusa 8) we have a flour which seems to be a compromise between the lively granular flour just mentioned, and the soft white flour such as that from the Pissis, yet it is really strong. If as a miller I could not have both, I would choose the White Jana Khar, but many millers would not, and it seems to me that No. 26 (Pusa 8) should be tested exhaustively in several districts. It is in my opinion a most promising wheat. Several others are also well worth attention, and I hope that from among the very best, or from among the merely better sorts of those submitted to me, one or several may be found to give best possible yields of grain and money to the producer in many or all parts of India."

ALBERT E. HUMPHRIES.

WEYBRIDGE, SURREY.

The 22nd October 1909.

It will be observed in the above report that considerable stress has been laid on the question of yield. We do not consider it out of place to discuss this aspect of the subject in the light of Indian conditions. As is well-known, several of the winter wheats in Great Britain are about the highest yielders of any wheat varieties in cultivation. From the point of view of the English farmer high yielding power is a paramount characteristic of any wheat brought to his notice. However high the quality of the grain it will not pay him to grow wheat which does not also yield well.

To effect any improvement in the wheats of Great Britain quality and yield must be combined and it is to the solution of this problem that Professor Biffen and Mr. Humphries are devoting their attention. A little consideration of the conditions of wheat growing in Great Britain shows that the growth period is a long one and the supply of nitrogen and water in the soil is ordinarily sufficient. Under these circumstances and provided the summer is not too cold, heavy yields are obtained. According to Hall and Russell,¹ who have recently made a study of the Rothamstead Experiments with a view of ascertaining the factors which determine the yield of wheat, yield of grain is proportional to the nitrogen supplied and further the type of soil in relation to climate is a very important factor. To each soil type there is a limiting yield beyond which the crop will not go but this limit is not the same for all varieties of wheat.

The conditions under which wheat is grown in India are very different from those in Great Britain and are not comparable with them. A brief experience of actually growing wheat in India rapidly impresses the existence of several limiting factors, for example, the duration of the growth period, the available moisture, the amount of nitrogen in the soil and the temperature.

The most important factor in the production of wheat in India and one which cannot be altered is the duration of the period of growth. Such practices as early and late sowing of wheat in India are impossible except to some extent in the Punjab. In the Gangetic plain and on the black cotton soils of Peninsular India, the period during which wheat can be sown safely is a brief one and the best time is roughly about the middle of October. Too early sowing results in the destruction of the seedlings by heat and white ants. Too late sowing results in defective germination and in a poor crop. As a rule it is more dangerous to sow too early than a little too late. At Pusa, there is a period of about 7 days after October 20th for sowing during which wheat gives the best results. The termination of the wheat growing period at harvest time is equally sudden. The rapid rise in the temperature which begins to set in towards the end of February, except in the Punjab, cuts short the possibilities of growth and often prevents ripening taking place. While wheat can ripen above a certain temperature it does not grow under these conditions and there is a

¹ *Nature*, October 14th, 1909.

well defined point after which the crop dries up no matter what stage it may then have reached. High temperatures therefore limit in both directions the growth period of Indian wheat. In the Punjab, sowings usually take place early in November, harvest begins at the end of April, and in this Province the duration of the wheat-growing period is longer. In all the wheat-growing tracts of India there are therefore clearly defined limits in both directions in which the wheat plant has, as it were, to compress all its activities. These activities can be divided into three well marked periods, namely, the early period including germination and growth up to the time tillering is completed. Then follows the stage when the wheat begins to shoot and the grand period of growth is ended by the formation of the ears and the fertilisation of the flowers. In the third period, ripening takes place or the translocation of the food materials into the grains of the ear. Over an average of years for any particular wheat tract there is a well marked total duration of growth which it is not safe to exceed. A wheat which cannot mature during this period whatever may be its characters and qualities is useless to the cultivators. It often happens that occasionally in any particular tract a wheat with a longer period of growth than the normal may give a good crop due to the accidental extension, that particular year, of the growth period caused by the late onset of the hot weather. Such a result is speedily reversed in trials extending over several years and it is found that any attempt in India to grow a variety with a longer growth period than the maximum safe period for that tract is bound to be a failure. The limitation in duration of growth of wheat in India is a grim fact and one which the wheat improver must learn to face at the outset. There are other reasons in addition to those of time, which make it desirable for any wheat variety to complete the grand period of growth as soon as possible, namely, the danger of rust. Rust attacks are most to be feared in January and February and as a rule the late wheats are damaged by rust to a much greater extent than the early ones. Again, early hot spells, with dry winds, are not unknown during the ripening period and these injuriously affect the later wheats to a much greater extent than the earlier types. The yield of any variety of wheat depends largely on its tillering power. Other things being equal, the greater the tillering power the greater the yield. A large amount of tillering however takes time and is impossible in India.

There seems to be a point beyond which it is not safe for Indian wheats to tiller and any tendency in the variety to tiller beyond this safe point, although admirable under other conditions, is a disadvantage in this country. We have to be content in India with those varieties of wheat which on an average of years ripen in the time the season permits. As the growth period is so short anything approaching a really high yielding variety is excluded. The experience obtained in acclimatisation work with wheat in this country points to the impossibility of ever obtaining high yielding wheats in India. High yielding English and north European winter wheats, when sown in the Gangetic plain, often do not even reach the shooting stage but spend the time in tillering. Even American and Canadian Spring wheats sown in the Punjab early in November cannot get through the growth period before the hot winds in May dry up the crop. The most that Canadian Red Fife did at Lyallpur in 1907 and 1908 was to form a few shrivelled grains with the help of several extra waterings. Had this wheat received the same treatment as the local sorts it is safe to say, on the two occasions on which it was grown by us at Lyallpur, it would not have yielded the weight of seed sown. Similar results were obtained with French, German, and Russian wheats both at Pusa and at Lyallpur. They all wasted their opportunities in tillering and were caught by the hot weather in many cases before any seed at all had set.

While the duration of the growth period in any tract limits the choice of varieties, the yield of these varieties is affected by several limiting factors. The most important of these is moisture. As a rule in India the available soil moisture is too small to give a full crop and the yield is limited by the water supply. Both on the black soils of Peninsular India and in most tracts of the alluvium irrigation increases the yield thereby proving the deficiency of moisture. In the irrigated wheat tracts of the alluvium the natural deficiency of moisture is not altogether made up by watering as the crop has too much water just after irrigation and often suffers to some extent before the next one. A shortage of soil moisture affects the yield especially at the tillering period. If the soil is too dry hardly any tillering takes place due to the poor development of the secondary root system. The great importance of the soil moisture factor has, in the non-irrigated wheat tracts such as the Central Provinces and Bihar, confined the growth of this crop

principally to the soils which retain moisture best. In the irrigated tracts lighter soils with only moderate power of moisture retention can be cropped with wheat. Although in most parts of India, moisture is generally in defect, wheat occasionally suffers from too much moisture, especially in years in which heavy rains fall just before and after sowing, towards the end of the growth period or at harvest time.

Another limiting factor, and this applies to the whole of the Gangetic plain and to Peninsular India, is the supply of nitrogen.¹ Taken as a whole the wheat crop of India suffers from a deficiency of nitrogen. Both on the black cotton soils and on the alluvium, wheat responds in a marvellous manner to nitrogen especially nitrogen in the form of organic manure. The wheat experiments conducted for many years at Cawnpore and at Nagpur amply bear

¹ There is one important method of increasing the nitrogen supply of the soil in the plains of India without manure of any kind. Moreover, it is one which does not seem to be sufficiently adopted in practice. To increase the supply of nitrogen for a wheat crop without applying any manure and without the growth of a leguminous crop seems at first sight an absurd statement. This method of nitrogen manuring for wheat consists in the exposure of the soil by several ploughings to the sun and air during the intensely dry hot weather of April, May and June. The exposure of the soil at this period has an astonishing effect on the succeeding wheat crop and undoubtedly increases the nitrogen available as is seen in the dark green luxuriant foliage. When the soil for wheat is not weathered during this hot dry period, the crop is yellow and stunted and exhibits all the characteristics of nitrogen hunger. We observed the extraordinary effect of weathering the soil on wheat and other *rali* crops soon after taking up land at Pusa in 1905, and we have frequently noticed the poor crops which result when this weathering has been omitted. In the Punjab, the wheat stubbles are often left untouched after the harvest and are not ploughed till September or October just previous to sowing. This practice is in our opinion most objectionable. More crop increase both in quality and yield would probably result from a proper weathering of the wheat soils of India immediately after the previous harvest than from any other treatment. The Indian cultivator has at his command a method of nitrogen manuring for wheat which is perhaps the cheapest in the world. A series of well designed demonstrations in the Indo-Gangetic plain to show the great effect of weathering the soil before wheat would we consider confer a great advantage on the cultivator. The explanation of the extraordinary effect of weathering is no doubt due to the partial sterilisation of the soil by the intense dryness, heat and light of an Indian hot weather. In all probability these causes bring about a similar result to that produced by artificial heating and by poisons such as has been found in England by Russell and his pupils (*vide Journal of Agricultural Science*, Vol. III, 1909, p. 111). These investigators have found that partial sterilisation of the soil kills off the phagocytes, which live on bacteria, and also large soil organisms inimical in other ways to bacteria. At the same time the soil bacteria are killed off but the spores remain which germinate and rapidly multiply when the soil is moistened. The new bacterial cultures increase at an enormous rate and the resulting nitrogenous plant food becomes so great that plant growth is greatly stimulated. Russell's results seem to afford an adequate explanation of the extraordinary manurial effect of weathering Indian wheat land. For exposing the soil during the hot season iron ploughs are more effective than the native wooden plough. This is no doubt due to the soil inversion produced by the former resulting in a more complete weathering and sterilisation of the soil.

out the paramount importance of nitrogen, while an inspection of the crops of the cultivators indicates the need of this element. In the Chenab Colony of the Punjab, the supply of nitrogen appears to be not inadequate. The wheat crop here is exceedingly vigorous and the dark green colour of the foliage points to an ample supply of nitrogenous manure. This state of affairs is in all probability due to the extreme prevalence of a bottom growth of leguminous weeds in the wheat fields of the Punjab which appear to confer on the soil all the benefits of a leguminous rotation (*vide Agricultural Journal of India*, Vol. I, 1906, p. 403).

Enough has been said to indicate the probability that both the varieties grown in any tract and also the yield will depend first of all on the duration of the growth period. For each wheat tract it seems to be necessary to consider only those wheats which will mature in the maximum safe period corresponding to that tract. Thus in Bihar, the period is shorter than that of the upper Doab, the home of Mozaffernagar white, and much shorter than that of the Canal Colonies of the Punjab. We should expect to find the yield increase with the duration period and to get higher yields in the Canal Colonies than in Bihar. Other things being equal, it is not likely that a wheat suitable for growth at Lyallpur in the Punjab would suit north Bihar, while a wheat which does well at Pusa is likely to mature too quickly on the Chenab. It will be interesting to discover to what extent the varieties suitable for growth at Pusa will differ from each other in yielding power. It seems not improbable that these differences will not be great. Further it remains to be seen in what manner such limiting factors as moisture and nitrogen differently affect the yield of these varieties. But little attention seems to have been paid in India to this aspect of the scientific study of varieties. The only published work seems to be that of Dobbs¹ who found at Lyallpur that the varieties tested there had approximately the same cropping power. At Pusa, we are investigating this subject and are using for the purpose pure culture wheats differing to some extent in growth period and very greatly in agricultural characters and grain quality. It will be interesting to see whether these wheats will show any great differences in yielding power and how they will be differently affected by short moisture and by a deficiency of nitrogen. We consider it highly probable that the choice of the

¹ Dobbs, *Report on the Lyallpur Agricultural Station*, 1907-08, Lahore, 1908.

best varieties will turn more on general agricultural characters, on rust resistance and on the quality of the grain than on the yielding power of the variety, provided the comparison is made between wheats which use up the whole of the maximum safe period of growth for the tract in question.

The significance of the above milling report to the wheat production and trade of India is very great. There is now no doubt that India can produce wheats with far greater flour strength and with far better milling qualities than the soft whites like the Mozaffernagar of the alluvium and the Pissis grown on the black soils of Peninsular India, both of which are so largely grown for export. Such wheats as the new Pusa wheats are worth more both to the cultivator for his own consumption and to the Home miller than the weak soft whites. We believe it will soon be demonstrated that several of the wheat growing tracts of India can grow wheats of a grain quality of the same class as Canadian and American Spring wheats and that these will command a much higher price in England than the present Indian wheats of commerce.

If the quality of Indian wheat could be improved by so little as two shillings a quarter (approximately four annas a maund) this would mean an annual gain to India of no less than 500 lakhs of rupees. Such an improvement in quality is easily possible and may without much difficulty even be exceeded.

Besides grain quality there are two other respects in which the Indian wheat crop can be improved namely in rust resistance and in the standing qualities of the straw. As a rule Indian wheats are very liable to rust and as a class they possess very weak straw.

The damage done by rust every year is very great. Watt¹ estimated the annual loss caused by wheat rusts at 10 per cent. of the value of the crop, an estimate which is certainly not an excessive one. Translated into money 10 per cent. of the value of the Indian wheat crop represents an enormous sum, over 400 lakhs of rupees in the case of the crop of 1889. The production of more rust resistant wheats with better straw by hybridisation, suitable for the various tracts would save a large portion of this enormous annual loss. Such rust resistant strong strawed wheats can be produced and indeed are being produced at Pusa at the present time.

¹ Watt, *Agricultural Ledger*, No. 20, 1895.

The production of new wheats which combine high grain quality with rust resistance and good straw characters might mean for the whole of India an annual gain to the country of some 900 lakhs of rupees or the addition of six million sterling to the wealth of India.

There is one method of improving the wheats exported to England which the cultivator and the trade have in their own hands. This is the growth and sale of wheats uniform in texture or consistency. Samples made up of soft, mottled and translucent grains such as those of Indian Fife and beardless Mozaffernagar grown on the Cawnpore Farm cannot be handled to advantage by millers. The sample must be uniform in texture. We have found that two of the most important causes of this unevenness of sample in India, apart from the growth of a mixture of types, are inadequate preparation of the land and the use of too much irrigation water. One of the best means of producing a uniform sample is to weather the soil during the previous hot weather and to plough it during the breaks in the monsoon in those tracts in which the wheat lands are fallowed during the *kharrif*. Where the preliminary weathering is neglected and the wheat lands are not broken up till late, the crop is almost invariably uneven in texture. The preliminary weathering seems to lead to a uniform absorption of water by the soil and to prevent local excess and defect of soil moisture. A uniform condition as regards soil moisture is naturally bound up with an even supply of moisture to the crop and this seems to be the chief cause of grain of even texture. If more attention were paid to preliminary preparation of the wheat land in India, we consider the milling qualities of the present Indian wheats would speedily be improved. In the Canal colonies of the Punjab, which furnish so much of the wheat for export, far too little attention is paid to preliminary cultivation. This is due no doubt partly to the size of the holdings but every effort should be made to induce the cultivators to till their land well and so improve the grade of wheat shipped from Karachi. If definite grades were also established and maintained by the trade and red and white wheats were kept separate still higher prices would be obtained.

Ptux,

The 18th November 1909.

